

# CSI: Sudden Cardiac Arrest

**Vincent C. Thomas, MD, MHA, FHRS**

**Pediatric Cardiology and Electrophysiology**

**Director of Medical Informatics for the Division of Cardiology**

**Associate Professor, Pediatrics- University of Nebraska  
Medical Center**

**Associate Clinical Professor, Pediatrics- Creighton  
University School of Medicine**





# Disclosures

- None

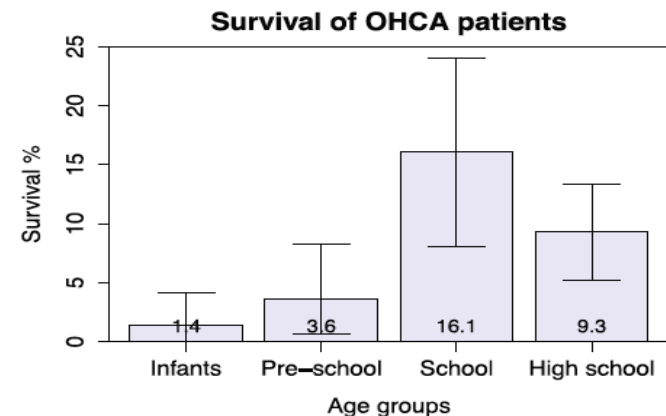
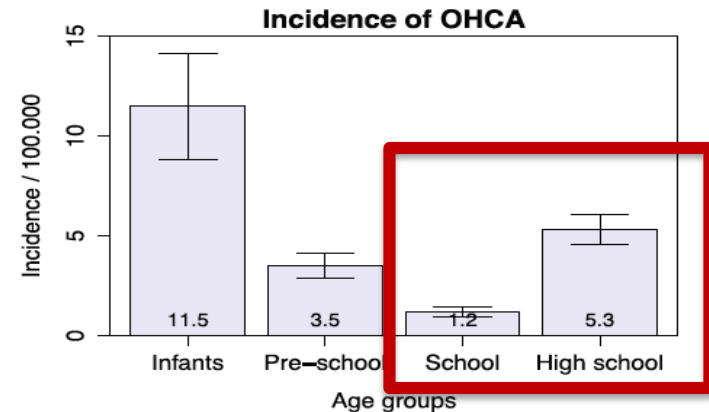
# Objectives

- By the completion of this talk, the attendee should be able to:
  - Discuss screening strategies for the prevention of sudden cardiac arrest
  - Identify the controversies over screening electrocardiograms
  - Review the importance of secondary prevention

# What is the incidence of SCA in the pediatric population?

- Meyer (Washington)
  - Under 35 years
  - 2.28 per 100,000 person-years
- Bardai (Netherlands)
  - Under 21 years
  - 3.2 per 100,000 person-years
- Atkins (US Epistery)
  - Non-traumatic OHCA
  - 8.04 per 100,000 person-years
- Harmon (NCAA)
  - 1 in 53703
  - 1.09 per 100,000 athlete-years
- Bagnall (New Zealand/ Australia)
  - 1-35 years (prospective)
  - 1.3 per 100,000 person-years

- Rajan (Denmark)



# What is the definition of a screening test?

- In diagnostic tests the use of a test which has a high sensitivity but often only a moderate specificity.
- Usually this is a quick and cheap test which is followed by a more expensive but more accurate test carried out on the positive reactors to the screening test.
- Sensitivity = tested positive/true positive
- Specificity = tested negative/true negative

# How do we prevent SCA?

## Primary Prevention

- Good History & Physical
- Further testing as needed

## Secondary Prevention

- Chain of Survival
- Use of CPR
- AEDs

# AAP History & Exam

## ■ PREPARTICIPATION PHYSICAL EVALUATION HISTORY FORM

(Note: This form is to be filled out by the patient and parent prior to seeing the physician. The physician should keep this form in the chart.)

Date of Exam \_\_\_\_\_  
 Name \_\_\_\_\_ Date of birth \_\_\_\_\_  
 Sex \_\_\_\_\_ Age \_\_\_\_\_ Grade \_\_\_\_\_ School \_\_\_\_\_ Sport(s) \_\_\_\_\_

**Medicines and Allergies:** Please list all of the prescription and over-the-counter medicines and supplements (herbal and nutritional) that you are currently taking

\_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

Do you have any allergies? ☐ Yes ☐ No If yes, please identify specific allergy below.

☐ Medicines ☐ Pollens ☐ Food ☐ Stinging Insects

Explain "Yes" answers below. Circle questions you don't know the answers to.

GENERAL QUESTIONS	Yes	No	MEDICAL QUESTIONS	Yes	No
1. Has a doctor ever denied or restricted your participation in sports for any reason?			26. Do you cough, wheeze, or have difficulty breathing during or after exercise?		
2. Do you have any ongoing medical conditions? If so, please identify below: <input type="checkbox"/> Asthma <input type="checkbox"/> Anemia <input type="checkbox"/> Diabetes <input type="checkbox"/> Infections Other: _____			27. Have you ever used an inhaler or taken asthma medicine?		
3. Have you ever spent the night in the hospital?			28. Is there anyone in your family who has asthma?		
4. Have you ever had surgery?			29. Were you born without or are you missing a kidney, an eye, a testicle (males), your spleen, or any other organ?		
<b>HEART HEALTH QUESTIONS ABOUT YOU</b>	<b>Yes</b>	<b>No</b>	30. Do you have groin pain or a painful bulge or hernia in the groin area?		
5. Have you ever passed out or nearly passed out DURING or AFTER exercise?			31. Have you had infectious mononucleosis (mono) within the last month?		
6. Have you ever had discomfort, pain, tightness, or pressure in your chest during exercise?			32. Do you have any rashes, pressure sores, or other skin problems?		
7. Does your heart ever race or skip beats (irregular beats) during exercise?			33. Have you had a herpes or MRSA skin infection?		
8. Has a doctor ever told you that you have any heart problems? If so, check all that apply: <input type="checkbox"/> High blood pressure <input type="checkbox"/> A heart murmur <input type="checkbox"/> High cholesterol <input type="checkbox"/> A heart infection <input type="checkbox"/> Kawasaki disease Other: _____			34. Have you ever had a head injury or concussion?		
9. Has a doctor ever ordered a test for your heart? (For example, ECG/EKG, echocardiogram)			35. Have you ever had a hit or blow to the head that caused confusion, prolonged headache, or memory problems?		
			36. Do you have a history of seizure disorder?		
			37. Do you have headaches with exercise?		
			38. Have you ever had numbness, tingling, or weakness in your arms or legs after being hit or falling?		
			39. Have you ever been unable to move your arms or legs after being hit or falling?		
			40. Have you ever been unable to move your arms or legs after being hit or falling?		

# AAP (cont'd)

HEART HEALTH QUESTIONS ABOUT YOU	Yes	No
5. Have you ever passed out or nearly passed out DURING or AFTER exercise?		
6. Have you ever had discomfort, pain, tightness, or pressure in your chest during exercise?		
7. Does your heart ever race or skip beats (irregular beats) during exercise?		
8. Has a doctor ever told you that you have any heart problems? If so, check all that apply: <input type="checkbox"/> High blood pressure <input type="checkbox"/> A heart murmur <input type="checkbox"/> High cholesterol <input type="checkbox"/> A heart infection <input type="checkbox"/> Kawasaki disease      Other: _____		
9. Has a doctor ever ordered a test for your heart? (For example, ECG/EKG, echocardiogram)		
10. Do you get lightheaded or feel more short of breath than expected during exercise?		
11. Have you ever had an unexplained seizure?		
12. Do you get more tired or short of breath more quickly than your friends during exercise?		
HEART HEALTH QUESTIONS ABOUT YOUR FAMILY	Yes	No
13. Has any family member or relative died of heart problems or had an unexpected or unexplained sudden death before age 50 (including drowning, unexplained car accident, or sudden infant death syndrome)?		
14. Does anyone in your family have hypertrophic cardiomyopathy, Marfan syndrome, arrhythmogenic right ventricular cardiomyopathy, long QT syndrome, short QT syndrome, Brugada syndrome, or catecholaminergic polymorphic ventricular tachycardia?		
15. Does anyone in your family have a heart problem, pacemaker, or implanted defibrillator?		
16. Has anyone in your family had unexplained fainting, unexplained seizures, or near drowning?		

<http://www2.aap.org/sections/sportsmedicine/PPEAbout.cfm>



# But how good is a history and exam?

- Meta-analysis
- 31 studies, total of 47,137 athletes
- Sensitivity and Specificity of each evaluation
- No clear data on history and exam

	Sensitivity	Specificity
History	20%	94%
Physical Exam	9%	97%
ECG	94%	93%

The effectiveness of screening history, physical exam, and ECG to detect potentially lethal cardiac disorders in athletes:

A systematic review/meta-analysis

Kimberly G. Harmon, M.D.,<sup>a,b,\*</sup> Monica Zigman, M.P.H.,<sup>a</sup> Jonathan A. Drezner, M.D.<sup>a</sup>

<sup>a</sup> Department of Family Medicine, University of Washington, Seattle, WA, USA

<sup>b</sup> Department of Orthopaedics and Sports Medicine, University of Washington, Seattle, WA, USA

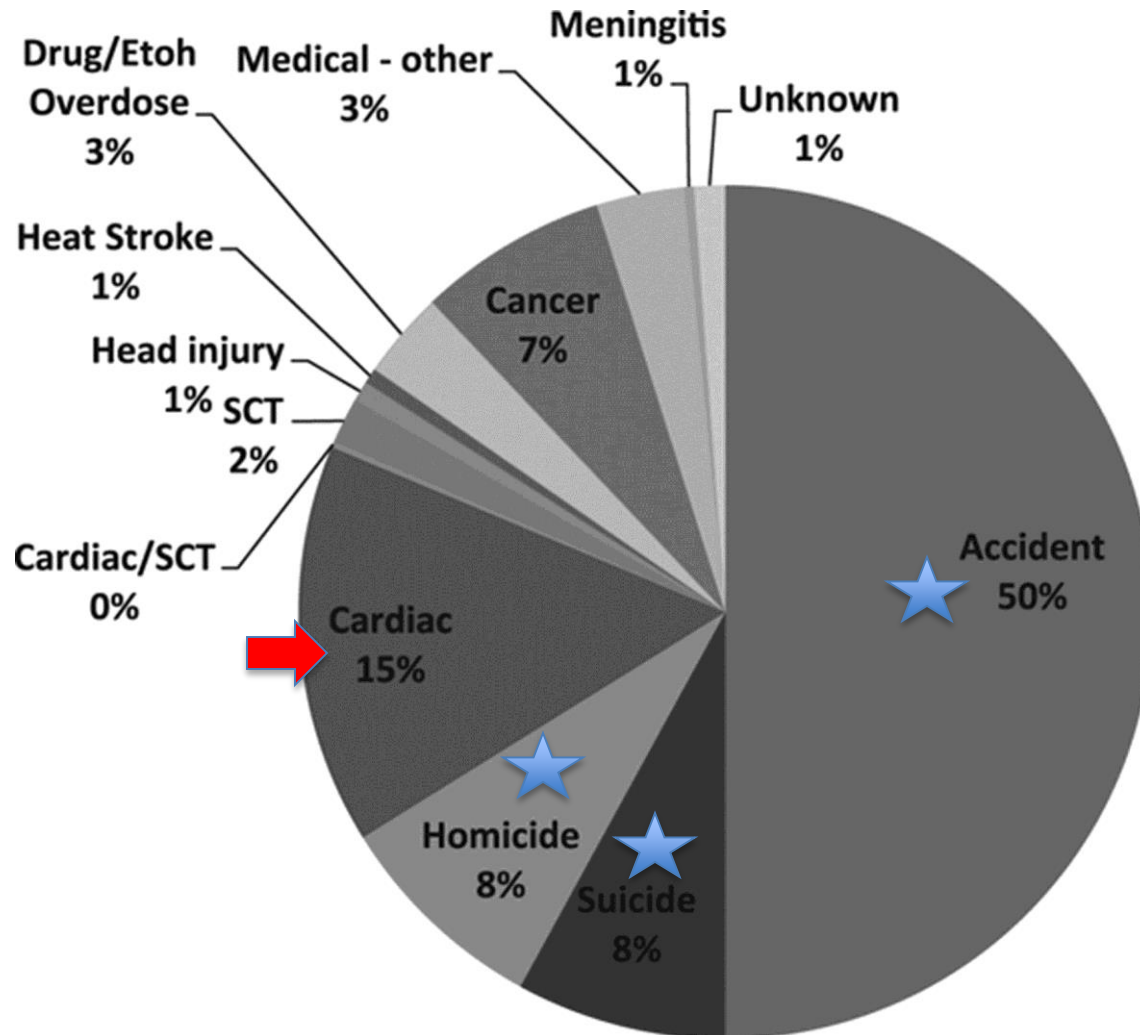
# Does an ECG qualify as a screening test?

- In diagnostic tests the use of a test which has a high sensitivity but often only a moderate specificity.
  - (97%, 93% respectively)
- Usually this is a quick and cheap test which is followed by a more expensive but more accurate test carried out on the positive reactors to the screening test.
  - (costs about \$30)
- YES

# Looking in More Depth

- Diseases Detected
- 160 potentially lethal conditions (0.3%)
  - WPW (42%)
  - Long QT (11%)
  - HCM (11%)
  - DCM (7%)
  - CAD, ischemia (6%)
  - ARVC (3%)
- Over half could not be diagnosed by history or physical exam unless symptomatic
- No coronary artery abnormalities detected




# Causes of death in NCAA athletes 2003 to 2013




Kimberly G. Harmon et al. Circulation. 2015;132:10-19

# Etiology

## Picked up by ECG




- WPW (~100%)
- Hypertrophic CM   
(~90%)
- Long QT (+/-) (~60%) 
- Short QT 
- Brugada (+/-)

## Maybe picked up

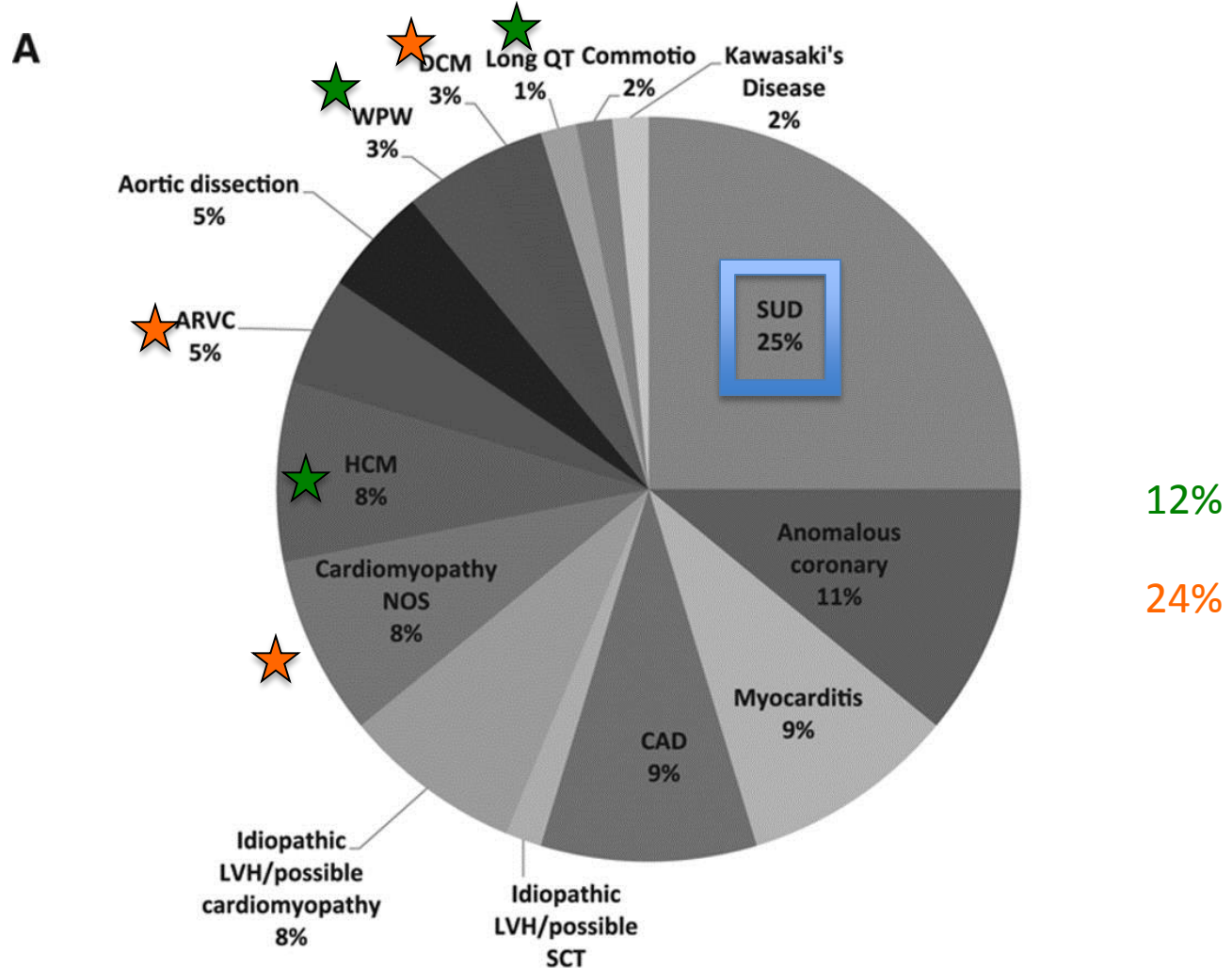
- Dilated CM
- Arrhythmogenic RV 
- Anomalous Coronary  
(rare- infants)

 May be picked up by family history (autosomal dominant)

## Not picked up by ECG

- Marfan Syndrome 
- Coronary artery  
disease 
- Pulmonary  
Hypertension 
- Commotio Cordis
- Idiopathic VF
- Myocarditis
- Kawasaki's Disease

# Causes of sudden cardiac death in athletes.



Kimberly G. Harmon et al. Circulation. 2015;132:10-19

# It's a matter of life and death!?!

- Pediatric and Congenital Electrophysiology Society
  - Task Force- led by Dr. Christopher Erickson
  - Findings and review are still pending
  - Avoiding the focus on two camps
  - Focusing on a guide for primary care

# It's a matter of public health

- Let's look at home...
- NE population (2015 census estimate)
  - 1,896,190 people
  - 24.8% under the age of 18 = 470,256
  - 5 minutes to read an ECG
  - 2,351,280 minutes = 39,188 hours = 4899 days (8-hour days) = 13.42 years
  - 3 electrophysiologists = 4.47 years each
- Cost = \$20/ECG = \$9.4 million
- Who gets an ECG? Just athletes? What's an athlete?



# False Positives

- Additional costs due to confirmatory tests
  - Cardiac consultation?
  - Echocardiogram?
  - Stress Test?
  - Electrophysiology study?
- Do we need to be concerned about socioeconomic disadvantage?

# False Negatives

- This is the scary part... testing negative in the setting of true disease
  - False sense of hope? What happens over time?
  - How about all the other causes of sudden death that cannot be found on ECG or autopsy?
    - Coronary anomaly
    - Commotio cordis
  - Liability concerns?

# Cost effectiveness?

- How would you use \$9.4 million in the state of Nebraska for public health initiatives?
- Would it be better to have an AED program where both children and adults could have life-saving treatment during an arrhythmia?

# Guidelines

**Mandatory and universal mass screening with 12-lead ECGs in large general populations of young healthy people 12 to 25 years of age (including on a national basis in the United States) to identify genetic/congenital and other cardiovascular abnormalities is not recommended for athletes and nonathletes alike (*Class III, no evidence of benefit; Level of Evidence C*).**

# So now what?

- Be the first line- advocate for these young students and athletes
  - Monitor for concerning signs and symptoms from young people
    - Chest pain that is always associated with activity
    - Syncope that occurs with exercise
    - New inability to keep up with other kids
    - Unusual heart beats associated with chest pain or syncope
- Work on creating an AED program for your school, club, association.
  - Not just installing an AED
  - Performing CPR and AED education
  - Practicing CPR and AED education
  - Creating a first-responder team
  - Increasing the availability of AEDs



# Secondary Prevention

# Secondary Prevention

- Initiating the Chain of Survival



- Survival for OHCA
  - Overall 7.6 to 7.9%
  - Effective CPR critical to this number
- Use of AED significantly important
  - For every minute AED not used, chance of survival decreased by 10%

# Disappointing



**Figure 1.** Bystander actions at actual out-of-hospital cardiac arrest events. The chart on the left indicates bystanders who had no training in cardiopulmonary resuscitation (CPR) (n=314); the chart on the right indicates bystanders who had received some training in CPR at any time in their lives (n=370). Green indicates the percentage of cardiac arrests in which bystanders performed CPR; red indicates the percentage of cardiac arrests in which bystanders did not perform CPR. Data shown are adapted from Swor et al<sup>14</sup> with permission of the publisher. Copyright © 2006, Society for Academic Emergency Medicine.



# Barriers and Misconceptions

- Agonal respirations
  - Gasping is NOT BREATHING
- Can't feel a pulse
- Concern about hurting with compressions
- Hesitation to use mouth to mouth
  - Hands only CPR
- Inappropriate shock with AED
  - Automated

# CPR Guidelines 2010

**Table 1. Summary of Key BLS Components for Adults, Children and Infants**

Recommendations			
Component	Adults	Children	Infants
Recognition	Unresponsive (for all ages)		
	No breathing, not breathing normally (eg, only gasping)	No breathing or only gasping	
	No pulse palpated within 10 seconds (HCP Only)		
CPR Sequence	CAB	CAB	CAB
Compression Rate	At least 100/min		
Compression Depth	At least 2 inches (5 cm)	At least 1/3 AP Depth About 2 inches (5 cm)	At least 1/3 AP Depth About 1 1/2 inches (4 cm)
Chest Wall Recoil	Allow Complete Recoil Between Compressions HCPs Rotate Compressors Every 2 minutes		
Compression Interruptions	Minimize Interruptions in Chest Compressions Attempt to limit interruptions to less than 10 seconds		
Airway	Head tilt-chin lift (HCP suspected trauma: jaw thrust)		
Compression to Ventilation Ratio (until advanced airway placed)	30:2 (1 or 2 rescuers)	30:2 Single Rescuer 15:2 2 HCP Rescuers	30:2 Single Rescuer 15:2 2 HCP Rescuers
Ventilations: When rescuer Untrained or Trained and Not Proficient	Compressions Only		
Ventilations with advanced airway (HCP)	1 breath every 6–8 seconds (8–10 breaths/min) Asynchronous with chest compressions About 1 second per breath Visible Chest Rise		
Defibrillation	Attach and use AED as soon as available. Minimize interruptions in chest compressions before and after shock, resume CPR beginning with compressions immediately after each shock		

# Recognition

**Table 1. Summary of Key BLS Components for Adults, Children and Infants**

Recommendations			
Component	Adults	Children	Infants
Recognition	Unresponsive (for all ages)		
	No breathing, not breathing normally (eg, only gasping)	No breathing or only gasping	
	No pulse palpated within 10 seconds (HCP Only)		

# Goodbye ABC's

**Table 1. Summary of Key BLS Components for Adults, Children and Infants**

Component	Recommendations		
	Adults	Children	Infants
CPR Sequence	CAB	CAB	CAB
Compression Rate		At least 100/min	
Compression Depth	At least 2 inches (5 cm)	At least 1/3 AP Depth About 2 inches (5 cm)	At least 1/3 AP Depth About 1 $\frac{1}{2}$ inches (4 cm)
Chest Wall Recoil	Allow Complete Recoil Between Compressions HCPs Rotate Compressors Every 2 minutes		
Compression Interruptions	Minimize Interruptions in Chest Compressions Attempt to limit interruptions to less than 10 seconds		

# Breathing

**Table 1. Summary of Key BLS Components for Adults, Children and Infants**

Component	Recommendations		
	Adults	Children	Infants
Airway	Head tilt-chin lift (HCP suspected trauma: jaw thrust)		
Compression to Ventilation Ratio (until advanced airway placed)	30:2 (1 or 2 rescuers)	30:2 Single Rescuer 15:2 2 HCP Rescuers	30:2 Single Rescuer 15:2 2 HCP Rescuers
Ventilations: When rescuer Untrained or Trained and Not Proficient	Compressions Only		
Ventilations with advanced airway (HCP)	1 breath every 6–8 seconds (8–10 breaths/min) Asynchronous with chest compressions About 1 second per breath Visible Chest Rise		

# Defibrillation

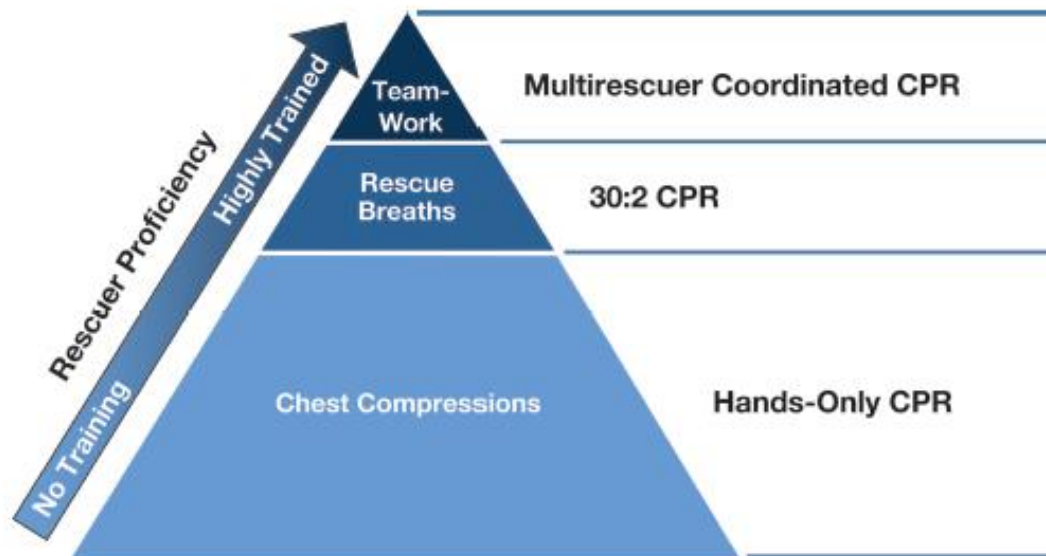
**Table 1. Summary of Key BLS Components for Adults, Children and Infants**

Component	Recommendations		
	Adults	Children	Infants
Defibrillation	Attach and use AED as soon as available. Minimize interruptions in chest compressions before and after shock, resume CPR beginning with compressions immediately after each shock		

# Hands Only CPR

Not to be used for INFANTS or CHILDREN

Not to be used for obvious asphyxiation or drowning victims



# The Importance of Practice

Nevada law requiring counties with > 1 million

- all high schools to have AEDs

Clark County School District

- 5<sup>th</sup> largest school district in the country
- Developed AED programs
- Actively drilled quarterly

*How do we make the process more efficient?*



# IDEAS: Improving Defibrillation Efficiency in Area Schools

**Table 1.** Variables Collected in the Study and Unit of Measure

**Table 3.** Results of Multivariable Mixed Regression Model on the TDFB\*

Independent Variable	Regression Coefficient	Standard Error	P value
Time to announcement (per s)	0.800	0.069	<.001
Distance of AED from drill site (per m)	0.230	0.054	<.001
Time to setup AED (per s)	0.002	0.122	.008
Distance of AED carrier from AED (per m)	−0.060	0.088	.493
Square meters per AED	0.001	0.001	.117
Total responders on AED team	−0.161	0.452	.723
Age of school building	0.060	0.166	.717
AED carrier characteristics			
Age of AED carrier (per y)	0.195	0.272	.476
BMI of AED carrier (per m <sup>2</sup> )	0.307	0.440	.487
Months of participation by AED carrier (per mo)	−0.044	0.075	.554
Female sex AED carrier	7.559	7.199	.296
Medical background of AED carrier	−5.086	7.198	.481
AED Use in real SCA by carrier	−1.588	6.811	.816

\*Variables excluded from analysis due to high correlation included time to start of CPR, time of arrival of AED, and students per AED. CPR, cardiopulmonary resuscitation; AED, automated external defibrillator; SCA, sudden cardiac arrest.

CPR, cardiopulmonary resuscitation; AED, automated external defibrillator; SCA, sudden cardiac arrest.

# SCA- Now what?



# We want FACTS

- Pre-Arrest:
  - How did the victim feel that day?
  - Were there any unusual actions taken by the victim?
  - Any new substances taken that day?
  - Any new medications that were started?
  - What were the circumstances around the arrest?
  - Did anything similar happen before?
- During Arrest:
  - Who was there and who witnessed it?
  - How did the victim go down?
  - Was the victim breathing or was it gasping?
  - Was there a pulse?
  - How did the victim look?
  - Was CPR performed? Who performed it?
  - Was an AED used? Where is the AED and what were its instructions?
  - Are there tracings of the event?

# We want FACTS

- Post Arrest
  - Which EMS team arrived first?
  - When did the victim regain consciousness?
  - How did the victim act when they regained consciousness?
  - Hold on to the AED...do we have new pads?
  - Any resuscitation equipment used that needs to be replenished?
  - Who was present at the event?

## WRITE IT DOWN

# Importance of Debriefing

- This is a scary event ...
- Lots of emotional disruption
- Can result in trauma to all involved
- Worth discussing and sometimes can involve psychological counseling
- Remember the “non-victims”...

# Summary

- Use your history and physical as a guide
  - Remember about family history
- Primary prevention is ideal, Secondary prevention works too (CPR & AED)
- Activate emergency response immediately
- Think of a crime scene: write down all the facts



# Thank you

# References

## References

1. Atkins DL, Everson-Stewart S, Sears GK, Daya M, Osmond MH, Warden CR, Berg RA. Epidemiology and outcomes from out-of-hospital cardiac arrest in children: The resuscitation outcomes consortium epistry-cardiac arrest. *Circulation*. 2009; 119: 1484-1491.
2. Meyer L, Stubbs B, Fahrenbruch C, Maeda C, Harmon K, Eisenberg M, Drezner J. Incidence, causes, and survival trends from cardiovascular-related sudden cardiac arrest in children and young adults 0 to 35 years of age: A 30-year review. *Circulation*. 2012; 126: 1363-1372.
3. Bardai A, Berdowski J, Van DW, Blom MT, Ceelen M, Van Langen IM, Tijssen JGP, Wilde AAM, Koster RW, Tan HL. Incidence, causes, and outcomes of out-of-hospital cardiac arrest in children: A comprehensive, prospective, population-based study in the Netherlands. *J Am Coll Cardiol*. 2011; 57: 1822-1828.
4. Maron BJ, Casey SA, Chan RH, Garberich RF, Rowin EJ, Maron MS. Independent Assessment of the European Society of Cardiology Sudden Death Risk Model for Hypertrophic Cardiomyopathy. *Am J Cardiol*. 2015; 116: 757-764.
5. Rajan S, Wissenberg M, Folke F, Hansen CM, Lippert FK, Weeke P, Karlsson L, Søndergaard KB, Kragholm K, Christensen EF, Nielsen SL, Kober L, Gislason GH, Torp-Pedersen C. Out-of-hospital cardiac arrests in children and adolescents: Incidences, outcomes, and household socioeconomic status. *Resuscitation*. 2015; 88: 12-19.
6. Maron BJ, Friedman RA, Kligfield P, Levine BD, Viskin S, Chaitman BR, Okin PM, Saul JP, Salberg L, Van Hare GF, Soliman EZ, Chen J, Matherne GP, Bolling SF, Mitten MJ, Caplan A, Balady GJ, Thompson PD, American Heart Association Council on Clinical Cardiology, Advocacy Coordinating Committee, Council on Cardiovascular Disease in the Young, Council on Cardiovascular Surgery and Anesthesia, Council on Epidemiology and Prevention, Council on Functional Genomics and Translational Biology, Council on Quality of Care and Outcomes Research, and American College of Cardiology. Assessment of the 12-lead ECG as a screening test for detection of cardiovascular disease in healthy general populations of young people (12-25 Years of Age): a scientific statement from the American Heart Association and the American College of Cardiology. *Circulation*. 2014; 130: 1303-1334.
7. Harmon KG, Zigman M, Drezner JA. The effectiveness of screening history, physical exam, and ECG to detect potentially lethal cardiac disorders in athletes: a systematic review/meta-analysis. *J Electrocardiol*. 2015; 48: 329-338.
8. Harmon KG, Asif IM, Maleszewski JJ, Owens DS, Prutkin JM, Salerno JC, Zigman ML, Ellenbogen R, Rao AL, Ackerman MJ, Drezner JA. Incidence, Cause, and Comparative Frequency of Sudden Cardiac Death in National Collegiate Athletic Association Athletes: A Decade in Review. *Circulation*. 2015; 132: 10-19.
9. Frommelt PC, Frommelt MA. Congenital coronary artery anomalies. *Pediatr Clin North Am*. 2004; 51: 1273-1288.
10. Bagnall RD, Weintraub RG, Ingles J, Duflou J, Yeates L, Lam L, Davis AM, Thompson T, Connell V, Wallace J, Naylor C, Crawford J, Love DR, Hallam L, White J, Lawrence C, Lynch M, Morgan N, James P, du Sart D, Puranik R, Langlois N, Vohra J, Winship I, Atherton J, McGaughan J, Skinner JR, Semsarian C. A Prospective Study of Sudden Cardiac Death among Children and Young Adults. *N Engl J Med*. 2016; 374: 2441-2452.
11. Bos JM, Towbin JA, Ackerman MJ. Diagnostic, prognostic, and therapeutic implications of genetic testing for hypertrophic cardiomyopathy. *J Am Coll Cardiol*. 2009; 54: 201-211.
12. Decker JA, Rossano JW, Smith EO, Cannon B, Clunie SK, Gates C, Jefferies JL, Kim JJ, Price JF, Dreyer WJ, Towbin JA, Denfield SW. Risk factors and mode of death in isolated hypertrophic cardiomyopathy in children. *J Am Coll Cardiol*. 2009; 54: 250-254.
13. Fitzsimmons PJ, McWhirter PD, Peterson DW, Krueger WB. The natural history of Wolff-Parkinson-White syndrome in 228 military aviators: a long-term follow-up of 22 years. *Am Heart J*. 2001; 142: 530-536.
14. Pediatric and Congenital Electrophysiology Society (PACES), Heart Rhythm Society (HRS), American College of Cardiology Foundation (ACCF), American Heart Association (AHA), American Academy of Pediatrics (AAP), Canadian Heart Rhythm Society (CHRS), Cohen MI, Friedman JK, Cannon BC, Davis AM, Drago F, Janousek J, Klein GJ, Law IH, Morady FJ, Paul T, Perry JC, Sanatani S, Tanel RE. PACES/HRS expert consensus statement on the management of the asymptomatic young patient with a Wolff-Parkinson-White (WPW, ventricular preexcitation) electrocardiographic pattern: developed in partnership between the Pediatric and Congenital Electrophysiology Society (PACES) and the Heart Rhythm Society (HRS). Endorsed by the governing bodies of PACES, HRS, the American College of Cardiology Foundation (ACCF), the American Heart Association (AHA), the American Academy of Pediatrics (AAP), and the Canadian Heart Rhythm Society (CHRS). *Heart Rhythm*. 2012; 9: 1006-1024.